

Asbestos Cement Pipe and Cancer in
Connecticut 1955-1974

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Asbestos Cement Pipe and Cancer In Connecticut 1955-1974

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Abstract

The associations of the use of asbestos-cement (A/C) pipe in public potable water distribution systems with changes in Connecticut cancer incidence rates were analyzed. Eight measurements related to asbestos in town water, population density, and socioeconomic scores were tested for their association with increased rates of cancer incidence, using multiple regression. No consistent patterns of association were found. The study provided no evidence for changing current water distribution policies for Connecticut public water supplies because of A/C pipe use.

Concern that the use of asbestos cement (A/C) pipe in public potable water distribution systems might increase the risk of gastrointestinal cancer has stimulated studies in Connecticut. A basis for this concern has been the evidence that persons occupationally exposed to airborne asbestos have experienced higher than expected rates of peritoneal mesothelioma, gastric cancer, and perhaps colon cancer. A study of 17,800 asbestos insulation workers showed a two to threefold increased risk of cancer of the oropharynx, esophagus, stomach, colon, and kidney, which might have been associated with clearance and swallowing of airborne fibers (1). Analyses of cancer rates in areas where asbestos fibers have been found in the drinking water have not produced clear evidence of excess cancer rates. Studies in Duluth, Minneapolis, and St. Paul, (2,3,4) and in the Puget Sound area (5) did not produce evidence that asbestos in water had contributed to increased cancer of any of the anatomical sites studied. In Quebec (6) and in five California counties (7) some positive associations were found for some digestive sites.

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Asbestos fibers are known to detach from asbestos-cement (A/C) pipe distribution mains in some situations. In A/C pipe systems in Florida, Pennsylvania, Kentucky, and South Carolina, asbestos (chrysotile) fiber concentrations of over 10 million fibers per liter have been found (8). It is thought that some of the factors related to the chemistry of the water passing through the pipe, such as the addition of corrosion control chemicals, may be related to the number of fibers eroded into the drinking water.

In many Connecticut townships A/C pipe has been used, totally or partially, for over 30 years. Counts of asbestos fibers in water systems were rarely over 1×10^6 fibers/liter. Measurements showed that 16% of fibers (chrysotile) were more than 5 micrometers (μm) in length and 11% were greater than $10\mu\text{m}$. Since the preliminary investigation by Harrington et al. (9), which gave no indication that changes in the gastrointestinal cancer rates in Connecticut from 1935 through 1974 had been associated with the use of A/C pipe, substantially augmented information has become available (8). Further measurements of asbestos fibers in Connecticut town water supplies, and water quality information related to the potential for the leaching of asbestos fibers from A/C pipe into the water supply, have extended the data. The

data have been analyzed with more powerful statistical methods in this study.

Materials and Methods

To assess the possible influences of A/C pipe use on cancer occurrence in Connecticut, individual town cancer rates were entered into a regression equation as the dependent variable, while asbestos exposure indicators for each town were entered as independent variables (10). Over 40 years of cancer incidence data are available to the Connecticut Cancer Epidemiology Unit from the Connecticut Tumor Registry by town of patient residence; therefore, the independent variables related to the drinking water, asbestos fibers and A/C pipe were prepared by town. Data from the periods 1955-64 and 1965-74 were used. Asbestos effects attributable to individual town asbestos-in-water concentrations would not be demonstrable before 1955 because little A/C pipe was used before that date. Our preliminary analysis had shown no detectable increases in cancer incidence when the later (after 1953) rates across the state, adjusted for A/C pipe use, were compared with the 1935-53 rates (9).

For each of the 169 Connecticut townships, the following information was used: number of newly

Table 1:

Association of cancer incidence (O/E) at 8 primary sites with cancer exposure from asbestos/cement (A/C) pipe, population density and socioeconomic status in Connecticut towns, 1955-1964, 1965-1974.

Site, ICD-O ^a	MALE											FEMALE												
	P e r i o d	Asbestos indicators								Asbestos indicators														
		b	c	d	e	f	g	h	i	j	k	R ²	b	c	d	e	f	g	h	i	j	k	R ²	
All sites ^m	1 2								++ ++		0.22 0.32					- --			+ +		++ ++	++ ++	0.20 0.15	
Stomach (151)	1 2								-- --		0.24 0.24								+ +		++ ++	- -	0.22 0.06	
Colon (153)	1 2							+ +	++ +	++ +	0.30 0.14								+ +		++ ++		0.14 0.07	
Rectum (154)	1 2										0.11 0.11			++ ++									0.06 0.11	
Pancreas (157)	1 2	+						++ ++			0.17 0.11												0.07 0.04	
Trachea, bronchus, lung (162)	1 2							++ ++		++ +	0.32 0.32			+ +		- -			+ +	-- --		++ ++	++ ++	0.14 0.16
Urinary bladder (188.0-188.6, 188.8, 188.9)	1 2							+ +			0.17 0.03			+ +	- -				-- --				0.22 0.08	
Kidney, renal pelvis, ureter (189.0-189.2)	1 2			+							0.06 0.11			+			+				++ ++		0.18 0.07	

Table Notes

+ indicates a positive association with higher asbestos exposure.

- indicates a negative association.

+ or - = $p \leq 0.05$

++ or -- = $p \leq 0.01$

1. 1955-1964

2. 1965-1974

^a "International Classification of Diseases for Oncology". WHO, 1976(18)

^b Asbestos: fibers/liter x 10^6 in water, 1975.

^c Percentage of town population on A/C pipe, 1975.

^d Length of A/C pipe in miles per person, 1970.

^e Maximum age of A/C pipe, 1960, 1970.

^f Iron content in source water in mg./liter, 1975.*

^g Change in calcium, mg./liter by mile, 1975.

^h Corrosion control in use, 1975.*

ⁱ Water aggressiveness index: $[pH + \log_{10} (\text{calcium hardness} \times \text{alkalinity})]$ 1975.*

^j Number of persons per square mile, 1960 or 1970.

^k Town socioeconomic score, 1960 or 1970.

^m All cancer sites, except non-melanomatous skin.

R²: The square of the multiple correlation coefficient.

*For this variable, the higher the numeric value, the lower the supposed exposure to asbestos, therefore high association (+) with cancer incidence on this table indicates low values.

diagnosed cases of malignant neoplasms for primary site by sex, age (0-4, 5-9, . . . , 60-64, 65+) and the year of diagnosis. The 8 primary sites of cancer analyzed were "all cancer sites (excluding non-melanomatous skin tumors)," stomach, colon, rectum, pancreas, lung, urinary bladder, and the combination of kidney, renal pelvis, and ureter. (See Table 1 for *International Classification of Diseases* numbers.) United States decennial Census town populations by sex and 5-year age intervals were used to calculate age-specific and age-adjusted (1950 U.S. standard) rates.

Asbestos-related data were available as follows: for 82 towns in which public water supplies were delivered either partly or wholly through A/C pipe, chrysotile asbestos fibers per liter were measured (with the transmission electron microscope using the EPA analytical asbestos method) (8,11) at the source and in water that had passed through A/C pipe. None of these towns had asbestos values as high as 0.1×10^6 fibers/liter in source waters. For 11 non-A/C pipe towns for which source waters were known or suspected to contain naturally occurring asbestos fibers, fiber content was measured at the source. In the other 76 towns it had been determined that no A/C pipe was used, so the asbestos-in-water content was estimated as a very small non-zero value, 0.005×10^6 fibers/liter, which is below the limit detectable by current analytical methods.

The variables which were not direct measures of asbestos in the water, but which might influence the amount of asbestos released to the water when delivered through A/C pipe, were for the year 1975: age of pipe, length of A/C pipe, use of corrosion control chemicals in the water supply, level of iron in the water supply, change in calcium content of water after passing through a measured length of A/C pipe, and an aggressiveness index based on measurements of water acidity, calcium hardness, and alkalinity at the source [$\text{pH} + \log_{10} (\text{calcium hardness} \times \text{alkalinity})$]. (12). The proportion of the population of each town served by water delivered through A/C pipe was also

estimated for the year 1975. All the water quality measurements used as asbestos indicator variables were modified from published figures to a town level because public water supply districts were coterminous with town lines only in one case.

Two independent variables known to influence town cancer rates, namely town population density and town socioeconomic status (SES) scores, were also used (13-16).

The periods 1955-64 and 1965-74 during which A/C pipe had been used to any extent in Connecticut water supply systems were examined separately. From the observed age-adjusted town rate, and the rate expected based on state rates, an observed to expected (O/E) ratio was calculated and weighted by the expected number of cases.

The form of the regression was as follows:

$$y = a_0 + a_1x_1 + \dots + a_{10}x_{10}$$

where

y = O/E ratio for a town

a_0 = constant

$a_1 \dots a_{10}$ = regression coefficients for each of 10 independent variables.

x_1 = Town population density (person/sq. mile) 1960, 1970.

x_2 = Town SES score 1960, 1970.

x_3 = Percentage of town population served by A/C pipe, 1975.

x_4 = Maximum age of A/C pipe, 1975 (weighted).

x_5 = Average length of A/C pipe, miles per person served, 1975 (weighted).

x_6 = Iron content of source water delivered through A/C pipe (weighted).

x_7 = Corrosion control chemicals added to water delivered through A/C pipe, 1975, Yes or No, (weighted).

x_8 = Aggressiveness index for water at the source, 1975 (weighted).

x_9 = Change in calcium content, mg/liter per mile of A/C pipe, 1975 (weighted).

x_{10} = Asbestos fiber content of water (# fibers $\times 10^6$ liter, as measured by transmission electron microscope) delivered in town public water supply, either through A/C pipe or non A/C pipe (weighted).

For each variable that might indicate asbestos-in-water, a weighted average exposure was calculated for individuals in each town. For towns in which asbestos content of water had been measured after delivery through A/C pipe, the calculation was as follows:

$$x_{10} = \frac{[x_3 (\# \text{ fibers} \times 10^6/\text{liter})] + [(100-x_3) (0.005 \times 10^6/\text{liter})]}{100}$$

This assumes a minimum asbestos-in-water exposure for that percentage of the town's population not served by A/C pipe unless there were data to the contrary. For x_4 , maximum age of A/C pipe in a town, a correction has been made to the

midpoint of the cancer ascertainment period, 1960 or 1970. If a town had had A/C pipe for 5 years in 1975, the maximum age of pipe in 1970 would have been 0, and this town would have been treated as unexposed. This was based on the assumption that at least 5 years of exposure to asbestos fibers in water supplies would have been required for any cancer outcome to have become detectable.

The six variables, x_4 to x_9 , used as indicators of the risk of possible release of asbestos fibers from A/C pipe were also weighted.

Dummy values were assigned for that proportion of the town not served by A/C pipe. These values were not measured, but selected to indicate the lower risk of asbestos fiber exposure among populations not served by A/C pipe, a risk lower than the least risk to those on A/C

pipe. Although, most of the measurements were made, necessarily, long after the A/C pipe installation, comparisons of chemical parameters in water analyses indicated little change over the years.

The 10 variables were entered into the regression as independent variables, in order to consider the effect of each in the presence of the others upon the cancer rates. In a separate analysis, the six indicators of possible fiber leaching from A/C pipe were tested for correlation with the measured quantity of asbestos in water.

Results

1. Associations of Cancer with Asbestos and A/C Pipe Variables

Eight cancer sites were analyzed for male and female experience separately, for the two time periods for 169 Connecticut towns. Results are shown in Table 1 for the 1960 period as the number 1 and for the 1970 period as the number 2. For three of the indicator variables, the lower the numeric value, the higher is the estimated risk of exposure to asbestos fiber: iron content, addition of chemicals for corrosion control, and the aggressiveness index. In Table 1, therefore, risk of exposure rather than numeric value is indicated by the + and - signs. The +(-) sign indicates a regression coefficient significant at the 5% level ($p < .05$) and ++(-) indicates an association significant at the 1% level ($p < .01$). R^2 is the squared multiple correlation coefficient, which is an estimate of the proportion of the variation in the cancer rate associated with the independent variables.

Fairly consistent associations of certain cancer rates with town population density and SES are shown in Table 1. As population density increased, the "all sites" and lung cancer rates were higher in both men and women in both time periods. Colon cancer in the 1960 period was positively associated with population density both in men and women, and for men only in the 1970 period. A strong association of stomach cancer with density occurred in women in the 1960 period.

Socioeconomic scores of Connecticut towns were significantly negatively associated with stomach cancer in men both in the 1960 and 1970 periods, in women in the 1960 period, and with lung cancer in men in 1970. SES was also positively associated with male colon cancer in

1960, with lung cancer in females in 1960 and 1970, and with female kidney cancer in 1960. There was a strong positive association of SES for "all sites" of cancer in females in both periods.

There were a number of significant correlations between the asbestos-A/C pipe variables and the cancer rates. There were five associations out of 64 tests at $p \leq 0.05$ in the 1955-64 decade among men, and all indicated an increasing cancer incidence with an increase in the hypothesized risk factor. One cancer site, the pancreas, had two significant regression coefficients, one for lack of corrosion control in A/C pipe, the other for the level of asbestos fibers in water supply. ($R^2 = 17\%$). In 1970, pancreatic cancer in men again showed two significant regression coefficients, for age of A/C pipe and length of A/C pipe ($R^2 = 11\%$). There were no significant associations of pancreatic cancer incidence and A/C pipe factors among women in either time period.

There was a positive association of length of pipe with kidney cancer in both sexes in 1955-64. There were no significant kidney cancer associations with A/C pipe risk factors in 1970.

The other two positive associations in men, in the 1955-64 period, were lack of corrosion control for A/C pipe with bladder cancer, and high aggressiveness index of water with colon cancer. These were not observed elsewhere in either men or women.

Among men in 1965-74, in addition to the already noted positive associations for pancreatic cancer, there was a significant association of lack of corrosion control in A/C pipe with lung cancer incidence.

Among women in the 1955-64 decade, 8 significant associations with asbestos factors were observed, 5 positive and 3 negative, while in 1965-75 there were 4 positive and 3 negative associations. These showed no consistent pattern. For example, in the 1965-74 period, lung cancer in women showed a positive association with the percent of population served by A/C pipe, and negative associations with control of asbestos leaching by iron in water, and with the aggressiveness index of water.

The same analyses were carried out using only the 82 towns with some A/C pipe. Results were similar to those given in Table 1.

2. Associations of A/C Pipe Variables with Asbestos in Water:

To learn whether the measured quantity of asbestos in water was correlated with the indicators for asbestos in water, a second regression analysis was performed. The number of asbestos fibers per 10^6 /liter, as measured for each town water sample delivered through A/C pipe, was the dependent variable, and the indicators of risk of asbestos in water were entered as independent variables, as follows:

- x_1 = Iron content of water delivered through A/C pipe, mg/liter, 1975.
- x_2 = Corrosion control chemicals added to water delivered through A/C pipe, 1975. Present or absent.
- x_3 = Aggressiveness index at source for water delivered through A/C pipe, 1975.
- x_4 = Change in calcium content, mg/liter per mile of A/C pipe, 1975.
- x_5 = Maximum age of A/C pipe, 1975.
- x_6 = Average length of A/C pipe per person served, 1975.

There was no significant relationship between any of the indicators for assumed asbestos fiber leaching from A/C pipe and asbestos fibers as actually measured.

Discussion and Conclusions

These analyses give no consistent indication that use of A/C pipe in Connecticut public water supplies has been followed by increases in incidence either of "all cancers" or of the individual sites considered. The observed associations between male pancreatic cancer rates and asbestos indicator variables are not consistent internally. That is, they were attributable to different indicator variables in the two decades, and were less significant in the later decade; whereas, they should have been greater if they had been causally related to asbestos. The associations of lung cancer with asbestos indicator variables were notable in that two of four significant associations among women were opposite to each other; that is, two indicated a "protective" effect on women's lung cancer rates from asbestos risk indicators.

Given the generally negative findings, it is important to estimate the power of the regression analysis; that is, to compute what strength of asbestos effect, had such existed, would have been identified in the size of data set used. It was found that if there had been a 50% additional risk of cancer (all sites) in those towns with the highest asbestos levels as compared to those with the lowest levels, the probability (or power) of detecting this would have been well over 90% for each decade and sex. For individual sites, the power is less because of the smaller number of cases; the weakest analysis is for an effect of asbestos on bladder or kidney tumors, where the power is approximately 50% to detect a 50% increase in risk, or about 80% of detecting a twofold increase. For each of the other sites the power was at least 80% of demonstrating a 50% increase in risk. These figures are all applicable when using the conventional 5% level for testing significance.

The analytical methods were considerably more refined and powerful than those in our previous study, and environmental information was more detailed. Therefore, the lack of coherent evidence for cancer risks from use of A/C pipe is reassuring. It is consistent with most reports from other areas of the

United States. It is probably related to the fact that most Connecticut water supplies contained small concentrations of fibers and that the great majority of these fibers were shorter than 5 μm in length. Studies of diseases caused by asbestos have shown that fibers longer than 5 μm are more hazardous than shorter ones (17).

The methods for measuring asbestos fibers and for estimating the risks of leaching of asbestos from other water quality measurements are still relatively inaccurate. This was confirmed by the lack of intercorrelation of these postulated asbestos risk indicators in our study. Future work will require better methods for asbestos risk indicators as well as data on other trace contaminants, especially organics, that have been alleged to increase cancer risks. The results reported here provide no evidence for changing current water distribution policies for Connecticut water supplies because of A/C pipe use.

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